AD 658471

SP-2938

COST-EFFECTIVENESS ANALYSIS FOR THE FIRE SERVICE: AN OVERVIEW

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2 September 1967

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SP-2938

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by

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A-1162 REV. 4 65

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ABSTRACT

Examines the technique of cost-effectiveness analysis, including its advantages and limitations, and discusses its potential usefulness to the fire service.

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FOREWORD

This paper is one of a series of documents that discusses the benefits to be gained by more fully utilizing the nation's technological achievements for reducing or resolving fire protection problems.[1] In particular, the "systems approach" to these problems is advocated.

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[1] a. The Wingspread Conference: A Challenge to Action, H. F. Jarrett, System Development Corporation, SP-2937, 2 September 1967.

b. Technology and the Fire Service: Command Post Implications, H. F. Jarrett, System Development Corporation, SP-2731, 5 April 1967.

c. The Systems Approach to Fire Protection Problems: An Overview, H. F. Jarrett, System Development COrporation, SP-2031/000/01, 15 April 1967.

d. Technological Progress as it Affects the Fire Service of the Future, H. F. Jarrett, System Development Corporation, SP-1040, 29 May 1963.

e. The Systems Concept and its Application to Fire Service Problems, H. F. Jarrett, System Development Corporation, SP-782, 24 April 1962.

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COST-EFFECTIVENESS ANALYSIS FOR THE FIRE SERVICE: AN OVERVIEW

I. INTRODUCTION

Cost-effectiveness is becoming increasingly more important as a management tool both in the government and the business sector. The purpose of this presentation is to provide an overview of what exactly is meant by cost-effectiveness analysis, and to encourage its use by fire-service decision makers.

Considered separately, cost refers to the value of the resources you must expend to achieve a certain goal; effectiveness refers to how well you can achieve it. Striking a balance between these two factors is what is meant by cost-effectiveness analysis.

Performing such an analysis before committing one's resources to a particular project represents a fundamental task for those decision makers who seek to realize a given objective for the least cost, or, conversely, for those who seek to maximize results for a given cost. Certainly this task looms prominently before all managers during budget time, when mandatory slashes require decisions as to what will and what will not remain in the budget.

The term "cost-effectiveness," then, does not refer to something entirely new; rather, it indicates a more determined effort to balance resources with operational aims. For example, it could be employed to determine how engine houses should be distributed and manned within the constraints of a community's restrictive budget and its optimum fire service plan.

The significance of cost-effectiveness analysis today stems from the increasing sophistication of our methods in relating cost to effectiveness as compared with methods available only a few years ago. It has been referred to as "quantified common sense," which actually is close to what cost-effectiveness is all about.

For our purposes, we might think of cost-effectiveness as any analytic study designed to assist the decision maker in identifying a preferred choice to the solution of a problem from among various possible alternative solutions. Thus, if there is no freedom of choice in solving a problem, cost-effectiveness analysis is not an appropriate tool to use.

In a fire service context, typical analyses might deal with such questions as the distribution of manpower and equipment, frequency and scope of preventive maintenance of fire apparatus, vehicle and equipment specifications, modes of response to emergencies and a host of similar problems that fire chiefs encounter.

One stage of cost-effectiveness analysis requires a comparison of alternative courses of action in terms of their costs and their effectiveness in accomplishing a defined objective. For example, we might decide to buy garden hoses for some of our engine companies. There are a limited number of garden-hose manufacturers, and these are easily identified; thus our alternatives are well defined. The significant questions remaining are those of effectiveness and cost. The cost of each brand of hose can be estimated reasonably well; it would include such factors as initial cost, and depreciation and maintenance over a given period, say five years. Effectiveness could be evaluated by measuring one or more hose characteristics, such as water-handling capacity, durability, pressure-handling capacity, or weight per foot. This type of analysis, concentrating primarily on the comparison of alternatives, is an example of cost-effectiveness analysis in a particular concrete sense.

In a broader sense, we might find ourselves in a position (at least hypothetically) of having a given amount of dollars to spend however we choose in strengthening our fire department. In this case we need to examine closely our departmental goals, and look at all realistic alternatives for attaining them. Alternatives might include the acquisition of a helicopter or of radio-telephone equipment, construction of a new engine house, addition of a pumper, hiring of additional personnel, or some combination thereof. In this example alternatives are dissimilar, and determining what we want to do becomes a major issue.

The point is that when cost-effectiveness analysis is used to provide policy advice, other parts of the problem leading to the comparison stage may assume relatively greater importance in solving the problem than the actual comparisons. There are several reasons for this. First, it is mandatory to specify the right objectives; that is, to understand what we are attempting to accomplish. Second, all realistic alternatives for accomplishing objectives should be identified, if possible; this means discovering better ways for attaining what we want. Third, the influence of non-dollar values may serve to invalidate the entire analysis if these are not considered in appropriate perspective. For example, consider the resulting antagonism of a city manager or mayor if an alternative showing him in a bad light were chosen. Last, we must find a satisfactory way to measure performance if we are to assess effectiveness of alternative ways of accomplishing what we want.

These reasons serve to show that cost-effectiveness analysis is not a substitute for ingenuity, judgment, experience and common sense. It is a tool used in providing the decision maker with an analytical foundation for making sound objective choices among the various ways a problem might be solved or an objective met.

Before discussing the elements of cost-effectiveness methodology, it should be noted that various terms are used to identify this methodology, including systems analysis, operations analysis, operations research, systems engineering, cost-utility analysis and cost-benefits analysis. All have the same general meaning and do not differ in principle; any differences are in degree, emphasis and context. For our purposes we will consider them to be synonomous.

II. ESSENTIALS OF COST-EFFECTIVENESS ANALYSIS

The major aim of a cost-effectiveness analysis is to select from all the possible ways of accomplishing an objective, the most suitable. As an example, we might decide to provide supply and maintenance coverage continuously rather than on a five-day, 40-hour week basis. We would provide this broader coverage by having personnel constantly available to perform this function. Alternatively we could assign civilian and/or uniformed personnel for constant and immediate coverage, or have someone on call during those time periods when immediate coverage was lacking, or provide no formal coverage and hope for the best. Formally assigning personnel would give us constant coverage at a given dollar cost, placing personnel on call might cost us less, but would not provide the immediacy of our first alternative; providing no formal coverage would reduce day-to-day costs for salaries or compensatory time. The potential cost of this last alternative could be significant if a critical and immediate need arose for equipment available only at the supply and maintenance facility.

One might remark at this point, "So what else is new? I have problems and objectives to define; my experts and committees provide me with information and guidelines, while I examine alternatives and make decisions." Certainly all of us do these things in our personal lives as well as when

on duty. The contribution of cost-effectiveness analysis is that it provides us with a structure for making more systematic and effective use of judgment than any other means available. This does not mean that a high degree of objectivity is always attained; however, analysis does allow us to move toward greater objectivity to providing a systematic, organized structure from which to attack problems.

The elements of this structure are:

- Objective or objectives
- Alternatives
- Costs
- Models
- Criteria

Each of these elements is present either implicitly or explicitly in every cost-effectiveness analysis, or for that matter, in any analysis involving a choice.

Objective(s)

The statement of an objective or objectives is one of the first and most important tasks facing the analyst; in this stage, he comes to grips with the problem and attempts to discover the decision maker's objectives or goals. The analyst must thoroughly familiarize himself with the problem. He then examines strategies, processes and procedures, forces and hardware for estimating how well and at what cost they accomplish the defined goals.

This phase is illustrated as follows: Our city has just annexed a residential area that will require fire protection, and our immediate problem is to provide this protection to a degree consistent with that afforded

similar areas within our jurisdiction. (To keep our example from becoming too complex, let's assume that we have already developed measures of fire department effectiveness, and that these are applicable to our problem.) We are now in a position to investigate various ways for accomplishing our objective.

Alternatives

Alternatives are selected that are seen as fulfilling our goal or goals. These alternatives need not be interchangeable or perform the same function. (This was illustrated in our previous example of acquiring a helicopter versus construction of a new engine house, or other dissimilar alternatives.) In the fire protection problem involving annexation, our objective is more specific: comparing alternative means for providing a specified level of fire protection for the acquired residential area. The alternatives considered would likely reflect an extension of existing capabilities rather than something unique or different; such as addition and/or redistribution of current manpower, equipment and facilities. After formulating alternatives, we are ready to estimate the cost of each.

Costs

Costs are what we give up in pursuing our objectives in a particular way. This means that certain of our resources can no longer be used for other purposes. While costs are usually thought of in terms of money, their true measure is in terms of the opportunities they deny us.

In our annexation example, we might consider as an alternative the relocation of an existing company into the annexed area. This move denies the resources of the company (manpower and supporting equipment) to the area it currently covers, and so a cost is incurred. If we are to maintain the existing level of fire protection coverage in this area and in effect

neutralize this cost, we must provide the area with equivalent fire protection resources, and thus a similar cost remains with us. More subtly, if this relocation led to a lowering of company morale and subsequent performance, this too would constitute a cost. This non-dollar cost would be difficult, if not impossible, to quantify.

Models

A model is a representation of some real-life phenomenon. Its purpose is to provide a vehicle that can be manipulated and studied for gaining information, in our case, for relating costs to alternatives, and alternatives to objectives. A model may be as simple or sophisticated as one wishes or as one can design it to yield the kind of information desired, and it may be quantitative, qualitative, or both. It may be physical, as for example a miniature fire station with its associated replicas of personnel, fire apparatus and equipment, or it may be symbolic, like a mathematical equation. In any event, the model must be representative of that which is being studied. This does not mean that a one-to-one relationship must exist between the model and the real-life phenomenon, it means that the relevant features of reality should be accurately represented in the model.

In our annexation example, we might limit our modeling to a verbal description of the situation, and subjectively judge the consequences of our various alternatives. We would then be using verbal descriptions to predict the cost of each alternative and the degree to which each alternative attained our objective. Or we might study cost and effectiveness of each alternative by using mathematical formulas to represent the situation. Type of model selected depends upon the situation to be studied, time and money available, and sophistication of the analyst.

Criteria

A criterion is a regulating principle or standard that allows us to rank alternatives in preferential order so that the most promising can be selected, and provides a means for weighing cost against effectiveness. There are three generally applicable criteria:

1. Minimum cost to attain a given objective.
2. Maximum effectiveness with a fixed cost.
3. Maximum absolute difference between gain and cost.

The first, minimum cost, is illustrated when we draw up the specifications for a pumper and then seek one that meets these specifications at least cost. The second, maximum effectiveness, is illustrated when we have a fixed-dollar budget item and seek the best available product for the dollars allocated. The third criterion, maximum absolute difference between gain and cost, depends upon our ability to measure effectiveness and costs in the same kinds of units--for example, if effectiveness were measured in terms of estimated dollar reduction of fire losses, and costs in terms of dollars expended per time period.

In our annexation example, we would attempt to realize a specified level of effectiveness at minimum cost, and our criterion would be of the first type.

To recapitulate, actual analysis comes into play after we have identified and formulated a problem; that is, defined issues, set boundaries for the inquiry, stated our objectives, acquired necessary data, and selected alternatives. If it becomes necessary to discover or invent alternatives, these will become part of the analysis. Each alternative is assessed by means of a model or models permitting us to estimate the consequences of each alternative. These consequences tell us how effective an alternative

is in attaining its objective and what its costs are. The criterion provides the standard by which we can list our alternatives in order of preference.

Analysis usually does not proceed as smoothly as might be implied. Often we find that alternatives do not satisfy objectives, effectiveness measures do not adequately measure how well objectives have been attained, models used do not permit reasonably accurate predictions, and we are in doubt about the appropriateness. When such problems arise, we have little choice but to repeat the analysis until we are satisfied with our answer, or until our time or money is depleted.

III. ADVANTAGES OF COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness analysis can be applied to a range of problems of varying degrees of complexity. Military applications, for example, include force composition, research and development, weapons selection, manpower and logistics problems. These have counterparts in the fire service, with the possible exception of research and development, which a smaller fire department usually cannot fund.

Cost-effectiveness analysis can be applied to a decision-making situation as specific as deciding where to locate a fire house, or as broad as planning a total fire-department budget. Equipped with an analysis a fire chief is in a favorable position to defend his proposed budget, can meet fiscal officers on their own grounds and justify his position in the ways they look at fiscal problems. A competent analysis also can help a decision maker clarify his objectives, understand better the courses of action open to him, and provide him with an estimate of the costs, risks, and benefits of each alternative he considers. It may also assist his perception of the problem, and undoubtedly will broaden his basis for judgment.

IV. LIMITATIONS OF COST-EFFECTIVENESS ANALYSIS

As might be expected, there are limitations to analysis that restrict its ability to respond to all requirements of the decision maker. A major limitation is that one frequently must deal with inaccurate or vaguely defined information. Axiomatically, all analyses yield results that are no better than the data upon which they are based. Moreover, cost-effectiveness analyses often are asked to provide immediate answers. Intuition or "gut feelings" are then expediently substituted for analytical results.

Error can also be introduced by placing too much emphasis on the specific tools, for example, the model instead of on the basic problem. This can occur when the computer is used as a tool, and the analyst becomes so fascinated with the tool as to lose perspective of the problems he is attempting to solve.

A more serious pitfall is that of consciously or unconsciously structuring the analysis within one's specific and personal frame of reference. Our reactions to problems are limited by the context of our capabilities, perceptions, experiences, environmental and cultural backgrounds. Therefore we should be sensitive to our biases when we approach problems in a particular way because "that's the way we always have done it," or "it can't be done any other way."

Inherent limitations of cost-effectiveness analysis are a major reason why this type of analysis must be relegated to an advisory role. Three limitations have been identified and discussed within a military context by E. S. Quade[1] and are stated here with relatively minor modification since these would generally apply in analyses of fire service problems.

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[1] Quade, E. S. Cost-Effectiveness: An Introduction and Overview, P-3134, RAND Corporation, May 1965.

Analysis is Usually Incomplete

Time, costs and availability of competent personnel understandably place limits on how far we can take an analysis of any appreciable degree of complexity. If the analysis is to be timely, it must be finished before being obsoleted by events that change the situation upon which it is based. Costs can limit our analysis in several ways; we are all familiar, too familiar perhaps, with budget constraints that limit what we can undertake. Both tangible and intangible costs can limit the thoroughness with which we can investigate alternatives; for example, we could not set a Bel Air-type fire to check upon the effectiveness of a particular method of suppression. Apart from the cost, the reality of such an act, would be much too great. Less tangible costs are illustrated in the earlier example of our city manager or mayor. The potential cost of exploring this alternative exhaustively, of trying it out in real life, might be greater than we would care to risk.

The present limited availability of competent personnel to perform cost-effectiveness analyses is actually not an inherent weakness. However, it affects the extent to which the method can be employed by the fire service. It is recommended, therefore, that fire chiefs incorporate this type of analytical competence within their own departments or assure that it is made available to them.

Even with unlimited time, money and competent personnel to perform an analysis, we could not expect to embrace all the relevant aspects of problems of any complexity. For example, how do we quantify the flexibility of a fire department and its compatibility with other fire departments; or, how do we measure the contribution of a new snorkel to the prestige of a fire department? Measures for these kinds of things are lacking or inadequate, so we must resort to subjective judgments. The analyst can make his judgments, but may find these overruled by the decision maker who has

his own ideas about the situation. And so the subjective element again may exert a major influence on what is attained by the method.

Measures of Effectiveness Are Often Approximate

When one considers the value of each of various ways for attaining a goal (or goals) one is faced with questions of what is meant by effectiveness and how it is measured. For example, what do we mean by the effective suppression of a fire and how do we measure it in other than gross terms? We need rather precise information about the effectiveness of our activities in fulfillment of our objectives. This has presented a strong challenge to military weapons systems analysts, and undoubtedly will challenge analysts of fire service problems.

Ways to Predict the Future Are Lacking

Although it is possible to forecast general trends, there is no fully accurate way to resolve in detail the specific courses of action a fire department should pursue. Expanding technology makes prediction difficult, and our national trend toward urbanization is changing the fire problem. Also, where the study of urban problems is receiving greater attention, solutions may be found that will radically change the future nature of fire protection. These are but two of many factors that make accurate prediction impossible and cost-effectiveness analysis advisory in nature.

V. CONCLUSIONS

We have briefly examined the cost-effectiveness concept, the essentials of cost-effectiveness analysis, and some of its advantages and limitations. We ask: what is the practical value of this technique to the fire services in general and to fire department decision makers in particular? At the least, analysis offers a way to choose the numerical quantities related to a fire department so that they are logically consistent with each other,

and provides answers by processes that are available for inspection, are repeatable by others and modifiable as additional information becomes available. In contrast with other ways of making decisions, its method is empirical and therefore reflects many of the desirable attributes of science. It is available for the taking, and it remains only for the fire service to exploit its appreciable capabilities.

DOCUMENT CONTROL DATA - R&D

1. ORIGINATING ACTIVITY (Corporate author)
System Development Corporation
Santa Monica, California

2a. Unclassified

2b.

3. REPORT TITLE
Cost-Effectiveness Analysis for the Fire Service: An Overview.

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (Last name, first name, initial)
Jarrett, Hilton F.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
2 September 1967	17	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	SP-2938
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10. AVAILABILITY/LIMITATION NOTICES
Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSOR

13. ABSTRACT
Examines the technique of cost-effectiveness analysis, including its advantages and limitations, and discusses its potential usefulness to the fire service.

A-2735

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Cost effectiveness Fire service Systems approach						